Proceedings of 10th Asian-Pacific Regional IAU Meeting 2008, 1–2 (2008) Printed 4 February 2013 (APRIM LaTeX style file v1.0)

Rapid Binary Stellar Population Synthesis

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ABSTRACT
Binary stars are common and it is necessary to model stellar populations using binary stars. We introduce a method to model binary-star stellar populations quickly. The method can also be used to model single-star stellar populations. The method is called rapid stellar population synthesis and it is based on a statistical isochrone database of both single- and bianry-star stellar populations. The database can be obtained easily from the CDS (or on request to the authors) and can be used conveniently for most stellar population studies and colour-magnitude fits. The main feature of using such a technique for modeling stellar populations is that it can save much computing time. Comparing to the method which evolves binary-stars using stellar evolution codes directly, the rapid stellar population synthesis method takes only one of 200,000 of the computing time. Although we can use the database to model stellar populations quickly, the involved uncertainties in spectra synthesis is small ($\sim 0.8\%$). I also introduce the method that uses the spectral energy distributions (SEDs) of single stellar populations to model the SEDs of composite populations.

Key words: galaxies: stellar content, galaxies: evolution, galaxies: formation

1 INTRODUCTION

Because galaxies contain a lot of stars and the evolution of stars has been well understood. The technique of evolutionary population synthesis has been an important tool for studying galaxies, especially for studying their formation and evolution. Most works used single-star simple stellar population (ssSSP) models. However, there are many binaries in galaxies and binary interactions have significant effects on stellar population studies. It is necessary to model the populations of galaxies via both single and binary stars.

Although there are many isochrone databases or star evolution tracks that can be used for modeling ssSSPs, there is no suitable star evolution tracks for modeling bianry-star stellar populations (bsSSPs). Therefore, some previous works used a rapid binary evolution code (Hurley et al. 2002) to calculate the evolution of binaries, because the code can calculate the evolution of binaries quickly. However, it usually needs a big star sample for modeling bsSSPs, as we only know some distributions for the model inputs. In this case, it usually takes long period for calculation of the evolution of stars and then makes difficult to model stellar populations via binaries widely. This is more significant when modeling the evolution of galaxies. Aiming to solve the problem, an isochrone database for both single-star and binary-star populations was built and a rapid stellar population synthesis method was presented (Li & Han 2008).

The paper just aims to give a short introduction to the database of bsSSPs and show the rapid spectral synthesis for stellar populations and the rapid fitting for colour-magnitude diagrams (CMDs) of star clusters.

2 RAPID BINARY STELLAR POPULATION SYNTHESIS

2.1 The basis of rapid binary stellar population synthesis

The basis of rapid binary stellar population synthesis is the isochrone database of bsSSPs (Li & Han 2008). The main steps to build the data base is as follows. First, a star sample of 2000, 000 binaries of populations was generated using a Monte Carlo method. Second, the evolution of stars was calculated using rapid stellar evolution code (Hurley et al. 2002) with default parameters of the code. Third, the effective temperature ($T_{\rm eff}$, 2000-60000K) versus surface gravity (log g, -1.5-6) plane was divided into 1451 × 751 subgrids and the fraction of stars locating in each subgrid was calculated and saved. Usually, for a population, there are less then 20 000 subgrids containing stars. Therefore, the database gives the statistical distributions of stars of populations in a log g versus $T_{\rm eff}$ plane. In order to make the database more useful, it supplies the star distributions of populations for both the initial mass functions of Salpeter (1955) and that of Chabrier (2003). The input ranges for the metallicity and age of populations are 0.0001-0.03 and 0-15 Gyr, respectively.

Because the database supplies the distributions of stars

of stellar populations in the log g versus $T_{\rm eff}$ diagram, it is unnecessary to calculate the evolution of stars when modeling stellar populations. This can save a lot of computing time. In addition, because the database supplies some statistical distributions of stars on log g versus $T_{\rm eff}$ plane, rather than the the positions of each star, when modeling the integrated peculiarities of populations (e.g., calculating the spectral energy distributions of populations, hereafter SEDs), the results of many stars can be obtained via the same calculation. This can also speed up the process of modeling populations.

2.2 Modeling simple stellar populations

The isochrone database can be directly used to calculate the spectra or photometry of simple stellar populations, because the database supplies very the statistical isochrones of simple stellar populations. In fact, any spectral library and photometry library can be used to translate the log g and $T_{\rm eff}$ of stars into the spectra or photometries of populations easily.

2.3 Modeling composite stellar populations

Although early-type galaxies were thought to be close to simple stellar populations and they were usually investigated by simple stellar populations, it is better to study them via composite stellar populations, because more and more observations showed recent star formations in those galaxies. In order to get more information about star formation histories of galaxies, it necessary to build composite stellar population models. This can be easily done via the isochrone database of SSPs or the SSP models presented before. If one calculates the SEDs of composite populations via the SEDs of ssSSPs, the computing time will be very short, but it will take longer time to calculate SEDs from an isochrone database. In addition, one can also use the SEDs of bsSSPs to calculate the ones of composite binary populations. The SEDs of bsSSP can be found from our previous work (Li & Han 2008).

2.4 Modeling colour-magnitude diagrams

Colour-magnitude diagrams are powerful tools for studying the stellar populations and other characteristics (e.g., binary fraction, distance and colour excess) of star clusters. I introduce the method of using the isochrone database of populations to model the CMDs of star clusters. Because the isochrone database supplies the log g and $T_{\rm eff}$ of stars of stellar populations, the CMDs of stellar populations can be obtained via translating the log g and $T_{\rm eff}$ values into the colours and absolute magnitudes using a photometry library. Then one can fit the observational CMDs using the CMDs of populations. The stellar metallicities, ages, distances and colour excesses of star clusters can be determined. The main feature of using the CMDs based on an isochrone database to fit observational CMDs is its high fitting speed and reliability. The high fitting speed results from the small number of subgrids of populations. The high fitting reliability results from the comparison of the fraction of stars in each subgrid. In other words, when using this method to fit CMDs, the shapes and star distributions are compared at the same time. The results is actually more accurate compared to those determined only by the shapes of CMDs. Because the uncertainties of different parts of CMDs are different, it seems better to give different weights for different parts. Furthermore, the shapes of CMDs are usually affected by the fraction of binaries that are observed as single stars. When explaining the CMDs of star clusters, the effects of the fraction of undistinguishable binaries should be taken into account.

2.5 Modeling the spectral and photometry evolution of galaxies

In the studies about the formation and evolution of galaxies, the modeling of spectral and photometry evolution is important. The reason is that stars contribute mainly to the eyeable mass and the light of galaxies. Here I introduce a little about using the isochrone database of stellar populations to model the spectral and photometry evolution of galaxies. Because there are too many stars in a galaxy, using a statistical isochrone database instead of the evolution tracks of various stars to model galaxies is convenient. This will save much computing time. The main thought here is similar to that of modeling the SEDs and photometry of composite stellar populations, but the effects of dust and gas should be considered. In addition, it seems better to use some spectral libraries containing emission spectra, as there are many special activities such as large fraction star formations when galaxies evolve.

3 CONCLUSION AND DISCUSSION

I mainly present the applications of using a isochrone database of binary-star stellar populations to model binary-star populations. The application of the database and the SEDs of simple binary-star populations to model the CMDs of star clusters and the spectral and photometry evolution is also discussed. It is shown that the rapid binary population synthesis can be widely used in astrophysics studies, especially in the studies of galaxies.

ACKNOWLEDGMENT

We are grateful to Profs. Zhanwen Han and Gang Zhao for useful discussions and suggestions.

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